Space Technology Research Grants

Long-Term Rotational Dynamics of Defunct Earth-Orbiting Satellites

Completed Technology Project (2016 - 2020)

Project Introduction

While extensive research has been conducted to predict the trajectories of defunct high altitude satellites, the attitude dynamics of these objects are not well understood. Interestingly, many satellites are known to spin rapidly - with periods as short as several seconds - or have complex rotation states that change over time. My goal is to develop theories explaining and predicting the rotational behavior of defunct satellites in GPS-like and geosynchronous (GEO) orbits. To do this, I will build on previous research involving asteroids. This research suggests that the rotational behavior of defunct satellites is largely due to the Yarkovsky-O'Keefe-Radzievskii-Paddack (YORP) effect, a phenomenon in which solar radiation absorption, re-emission, and reflection produces torques on an orbiting body. In addition to the YORP effect, energy dissipated through structural flexibility or fuel slosh appears to play a key role in the rotation state evolution of defunct satellites. To investigate these effects as well as others, I will develop analytical and numerically integrated simulation models that couple attitude dynamics and orbital motion. These models will include solar radiation pressure (SRP), energy dissipation effects, gravity gradient torques, and n-body influences. To gain insight into the attitude dynamics and validate simulation results, I will collaborate with satellite observers to observe the spin states of particular defunct satellites. The information provided through simulations and observations will allow me to develop theories predicting the rotational behavior of defunct high altitude satellites. Understanding the attitude dynamics of these defunct satellites is important for trajectory prediction, collision risk assessment, and proposed satellite repair and recycling operations. Predicting the long-term orbital motion of these satellites requires accurate modelling of SRP, the strongest non-gravitational force affecting uncontrolled high altitude satellites. Like atmospheric drag, SRP forces are dependent on a satellite's orientation with respect to incoming particles (in this case photons and radiation from the Sun). However, many current orbital debris prediction models neglect attitude considerations when calculating SRP forces, instead assuming constant or at best time averaged SRP coefficients. Incorporating attitude dynamics information into orbital prediction models will yield more accurate pictures of the future orbital environment. Knowledge of a defunct satellite's spin rates will also help predict the potential for satellite break-up or material shedding, allowing operators to navigate critical assets away from these hazards. Finally, satellite repair and recycling operations, which promise to reduce the cost of operating expensive GEO satellites, require repair spacecraft to dock with rotating, uncontrolled satellites. Understanding the satellite spin states that the spacecraft might encounter will be crucial for success. Ultimately, the advancements permitted through an enhanced understanding of defunct satellite attitude dynamics will help protect critical space assets from collisions and ensure the safety of Earth's orbital environment for future users.

Anticipated Benefits

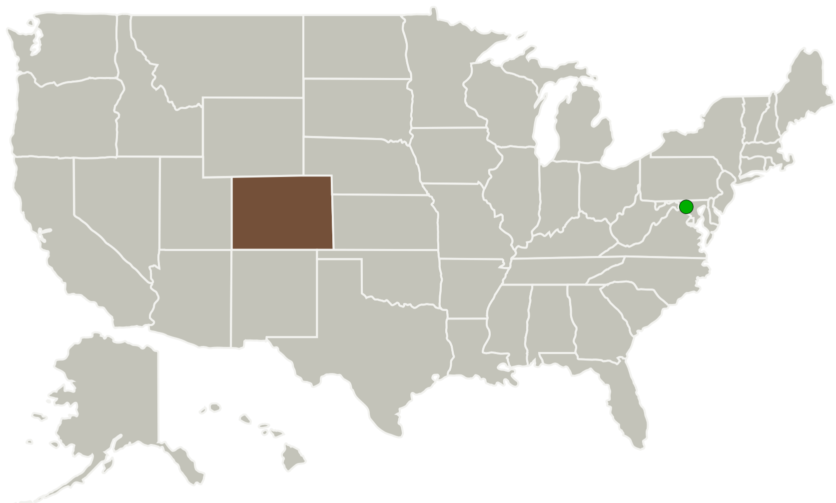
Long-Term Rotational Dynamics of Defunct Earth-Orbiting Satellites

Table of Contents

Project Introduction	1
Anticipated Benefits	1
Primary U.S. Work Locations and Key Partners	2
Project Website:	2
Organizational Responsibility	2
Project Management	2
Technology Maturity (TRL)	3
Technology Areas	3
Target Destination	3

Ultimately, the advancements permitted through an enhanced understanding of defunct satellite attitude dynamics will help protect critical space assets from collisions and ensure the safety of Earth's orbital environment for future users.

Primary U.S. Work Locations and Key Partners



Organizations Performing Work	Role	Type	Location
University of Colorado Boulder	Lead Organization	Academia	Boulder, Colorado
Goddard Space Flight Center(GSFC)	Supporting Organization	NASA Center	Greenbelt, Maryland

Primary U.S. Work Locations
Colorado

Project Website:

https://www.nasa.gov/strg#.VQb6T0jJzyE

Organizational Responsibility

Responsible Mission Directorate:

Space Technology Mission Directorate (STMD)

Lead Organization:

University of Colorado Boulder

Responsible Program:

Space Technology Research Grants

Project Management

Program Director:

Claudia M Meyer

Program Manager:

Hung D Nguyen

Principal Investigator:

Daniel Scheeres

Co-Investigator:

Conor Benson

Technology Maturity (TRL)

Start: **2**
Current: **2**
Estimated End: **3**

1	2	3	4	5	6	7	8	9
Applied Research			Development			Demo & Test		

Technology Areas

Primary:

- TX05 Communications, Navigation, and Orbital Debris Tracking and Characterization Systems
  └ TX05.6 Networking and Ground Based Orbital Debris Tracking and Management
    └ TX05.6.4 Orbital Debris Monitoring Software Platforms

Target Destination

Earth